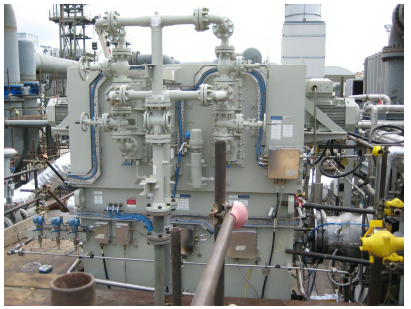
Case Study

Influence of Jacking Oil Supply Configuration on Shaft Vibration of a Super-Synchronous Motor

Tim Hattenbach, P.E.
Feroze Meher-Homji, P.E.
Bechtel Corporation Houston, Texas

Mark Sandberg, P.E.
Mike Larkin
Chevron Corporation, Houston, Texas

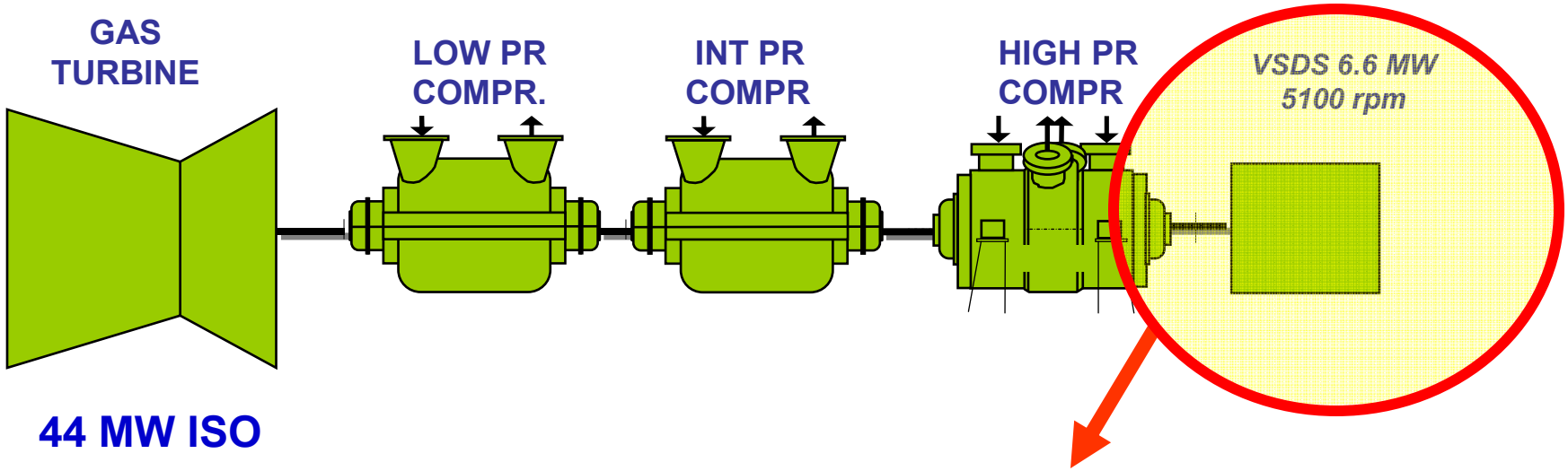


CASE STUDY: 38TH TURBOMACHINERY SYMPOSIUM

Presentation Outline

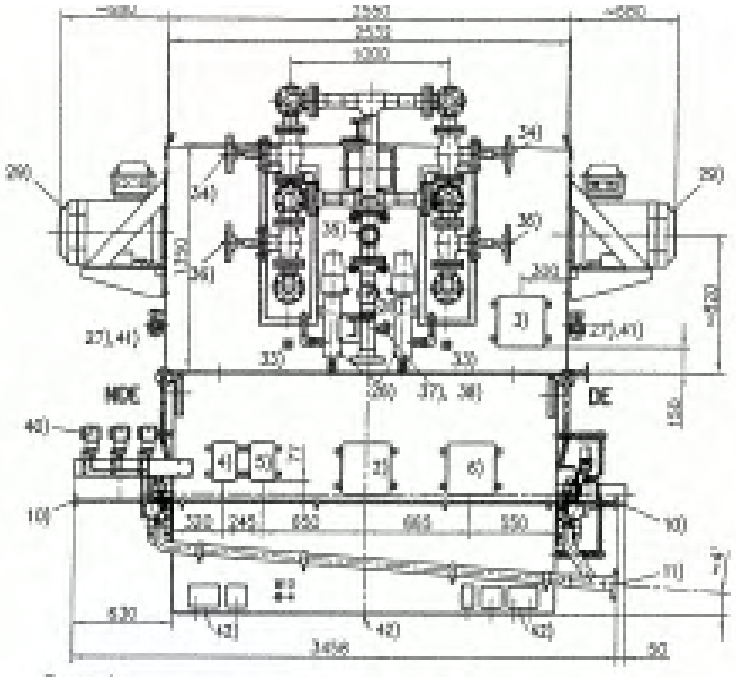
- **Background and Overview of Motor Sub-Synchronous Vibration Problem (SSV)**
- **Troubleshooting Procedures and Tests- Sequence of Events**
- **Bearing design modification - Unresolved vibration**
- **Further Investigation**
- **Shop Testing details- Success (4 months after initial discovery of issue)**
- **Final Successful String Testing**

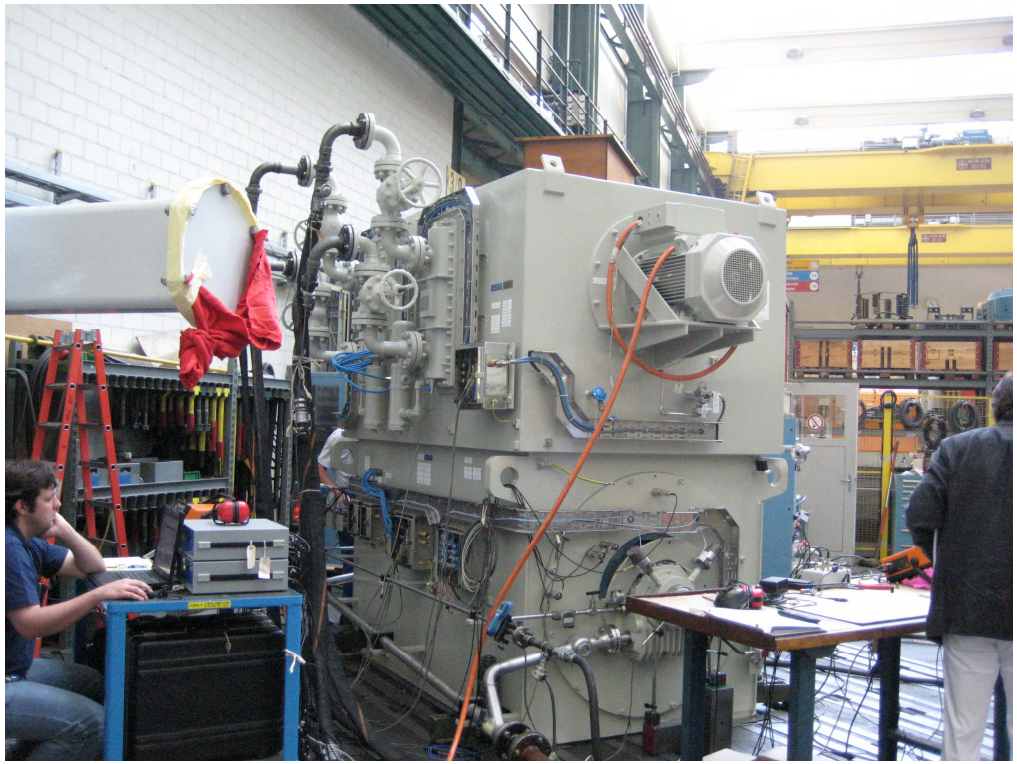
LNG STRING CONFIGURATION



6.6 MW, PWM VFD – Super-synchronous
6600 V , TEWAC
Mech Design to API 541, Elec Design IEC
N = 5110 RPM
Motor Wt = 15,800kg, Rotor Wt = 2200 kg
Bearing Span = 2.47 m
4 lobe, Fixed Geometry 160 mm Diameter Bearings

6.6 MW Electric Motor





Jacking oil (Nominal pressure 80 Bar) is supplied through hoses to motor bearings from a dedicated pump. The check valves are located outside the bearing housings

Used only during start up and shutdown

Initial Tests- Bearing Labyrinth Seal Problem

- **OEM conducted a test at 4200 RPM (82 % of Running Speed). This was the test speed in the OEM's original scope.**
- **Motor exhibited fractional harmonics of running speed**
- **Problem attributed to inadequate labyrinth clearances**

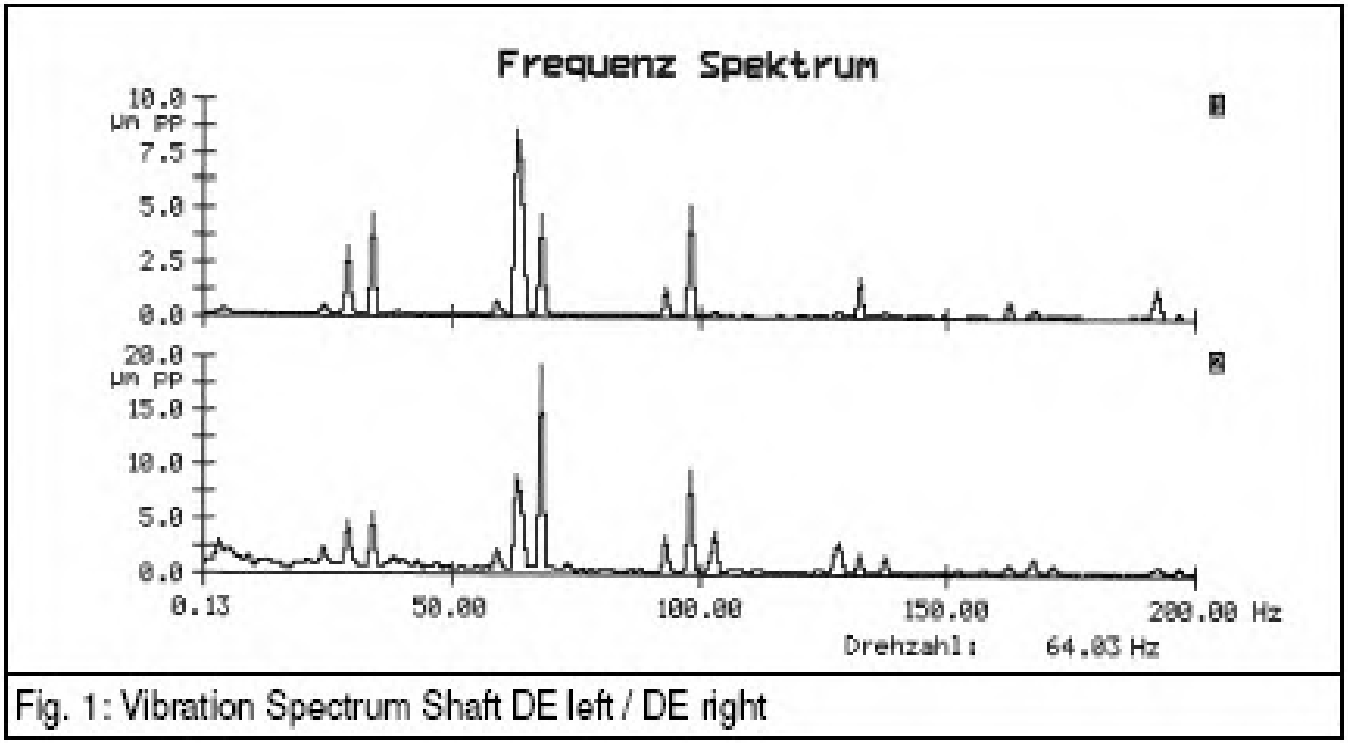


Fig. 1: Vibration Spectrum Shaft DE left / DE right

Initial Tests- Bearing Labyrinth Seal Problem

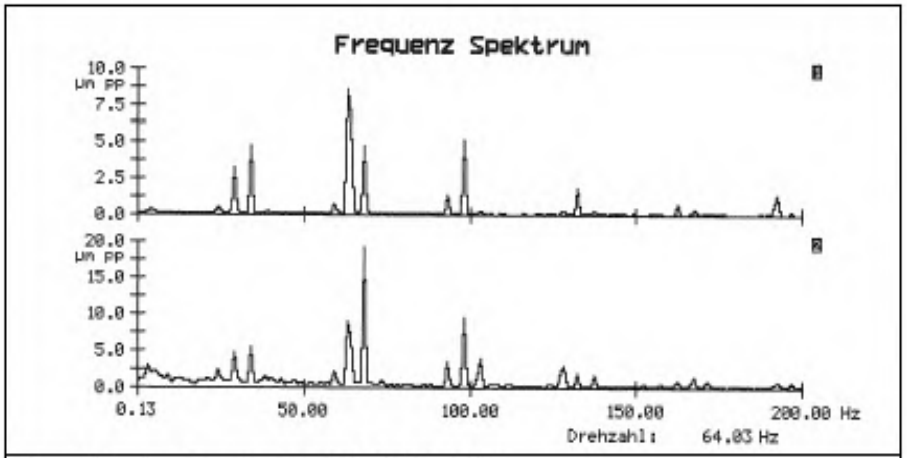
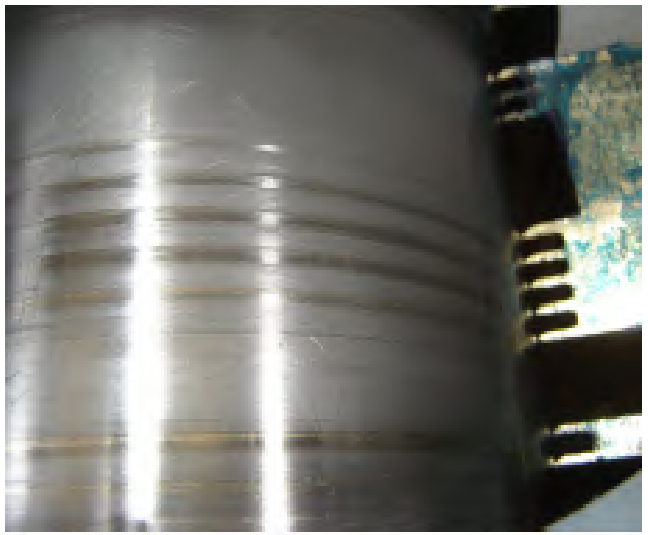


Fig. 1: Vibration Spectrum Shaft DE left / DE right

BEFORE



AFTER OPENING LABY CLEARANCES

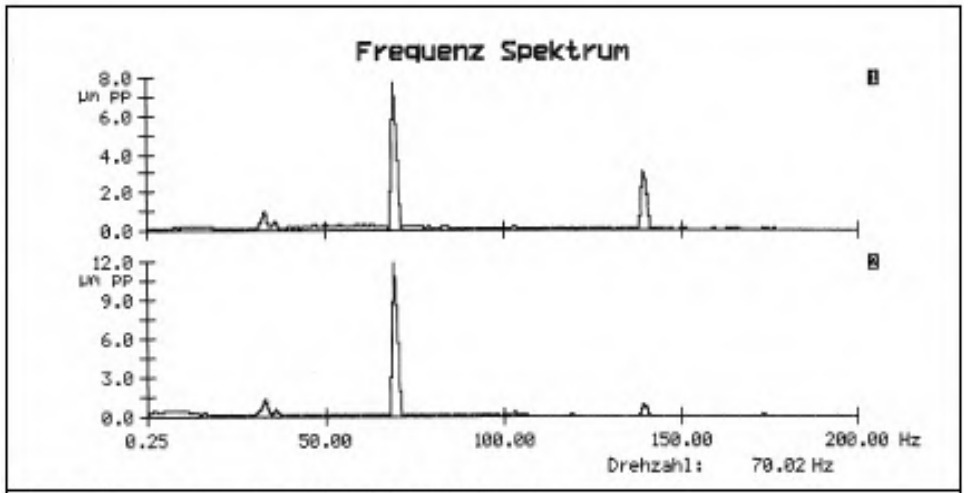


Fig. 5: Vibration Spectrum Shaft DE left / DE right

First development of SSV at 1st Critical

Motor tested at full speed using job VFD.

Max vibration 51 microns pk-pk -SSV noted at 1st Bending Critical and its second harmonic

High sub-synchronous vibration above 4800 RPM-Because of the contractors's insistence the motor was run at its rated speed 5100 RPM .The unfiltered vibration exceeded 50 Microns Pk-PK at the NDE Bearing-Clearly unacceptable

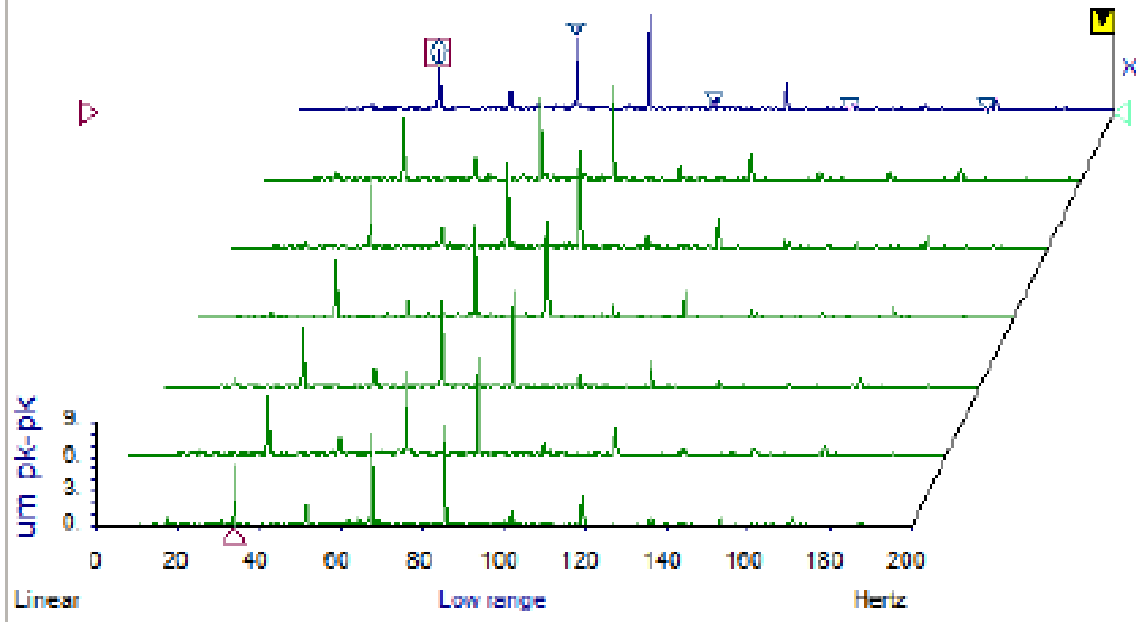


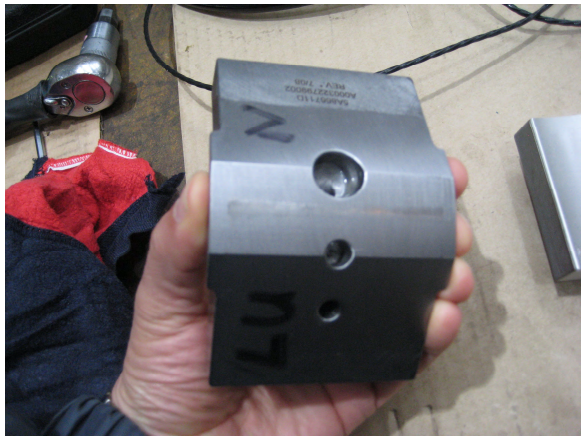
Fig. 4: Vibration Spectrum Bearing DE left during operation at 5110 rpm

First development of SSV at 1st Critical

Studies conducted on bearing design, bearing shell designs

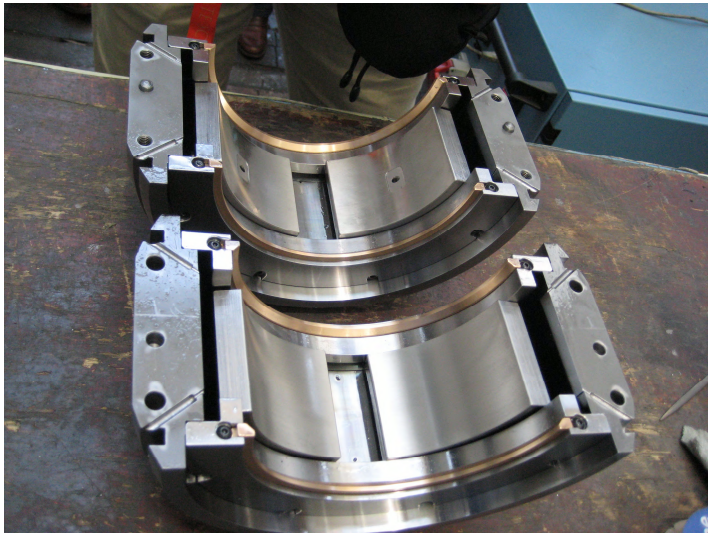
Root cause attributed to low damping and oil whirl in the 4 lobe bearings

4 lobe Load between Pads Tilting pad bearings designed to replace existing bearings- design constrained by existing bearing housing.



A new lateral analysis with the proposed revised bearing design-4 pad tilt pad bearings- Showed significantly improved damping

The jacking oil was now injected through a single hole in each lower tilting pad, connected by a hose and an external check valve (Same as with the 4 lobe bearing design)



Non-drive end side (SFT NDE) at Tin=42°C and 18 l/min/bearing

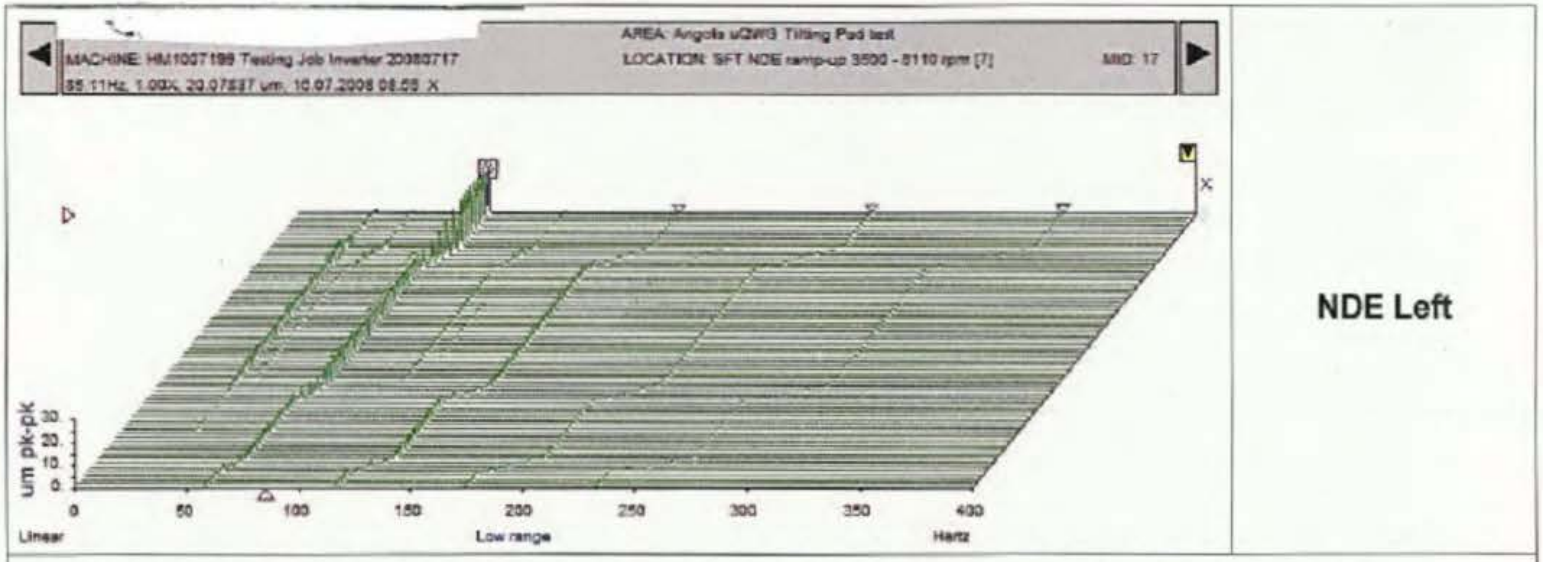


Figure 43: Waterfall plot of a ramp-up from 0 to 5110 rpm at **SFT NDE** (Test 2)

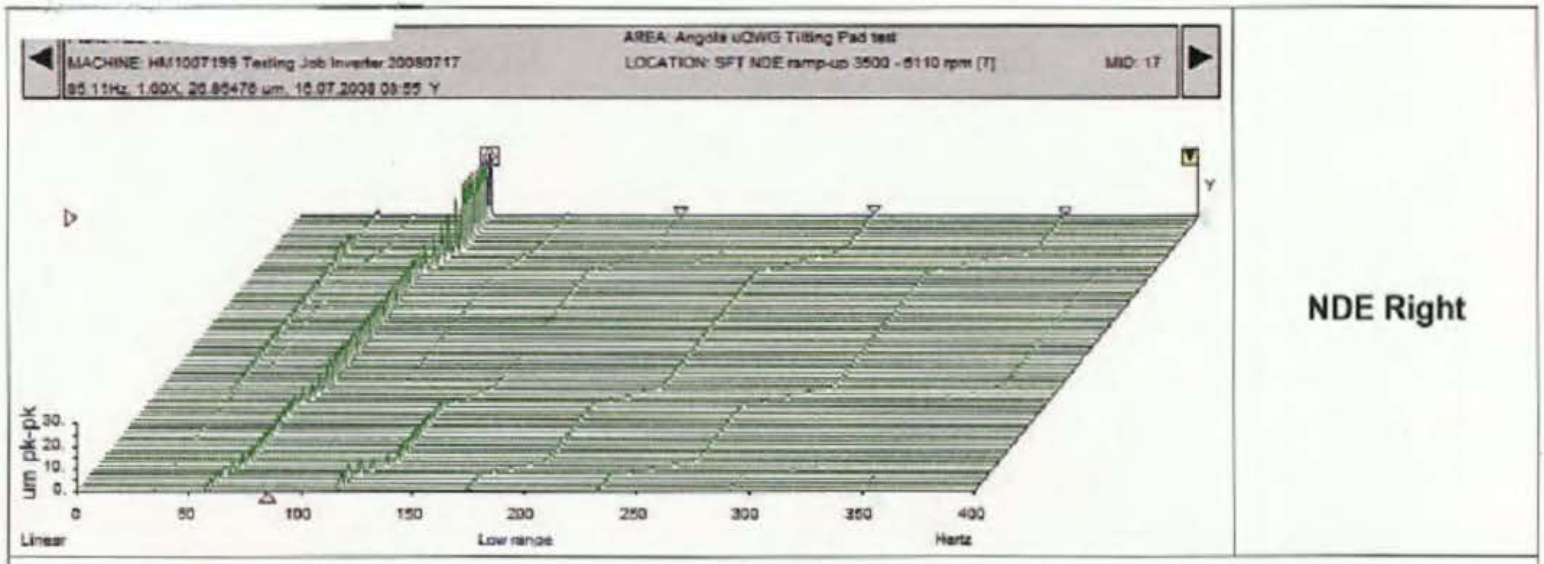
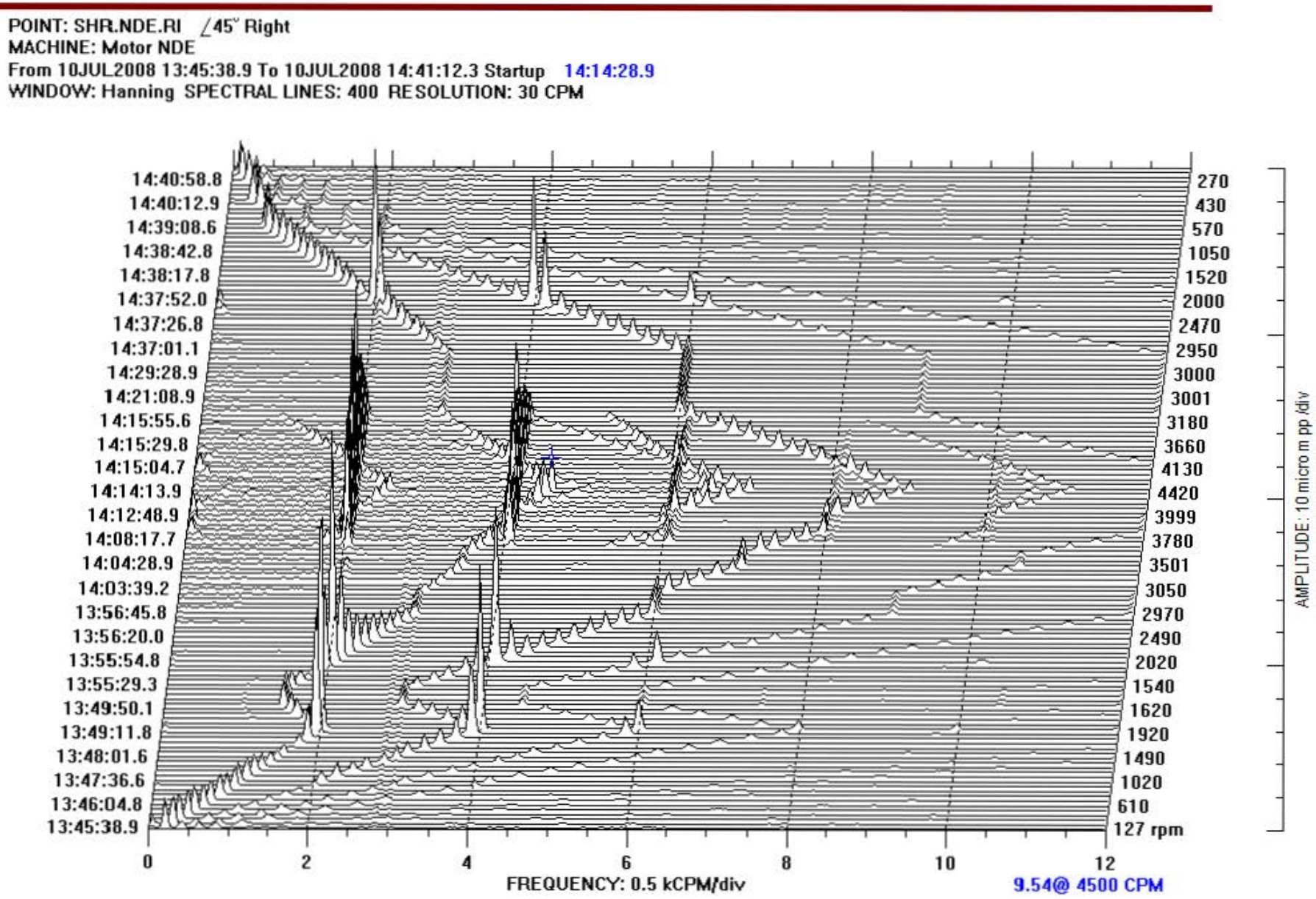


Figure 44: Waterfall plot of a ramp-up from 0 to 5110 rpm at **SFT NDE** (Test 2)

Witness Test with TPJs-Vibn too high to reach rated speed



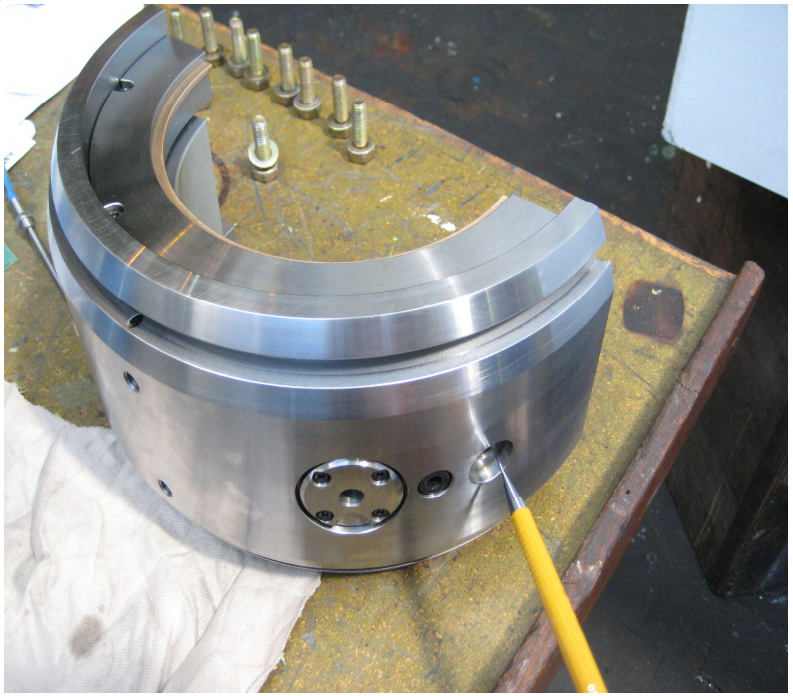
Subsequent Investigations Leading to Resolution

[A] Hole in Housing Left Open

Hole for spare RTD left unplugged allowing oil drain from housing

Hole Plugged and Machine retested.

Slight improvement but SSV persists.

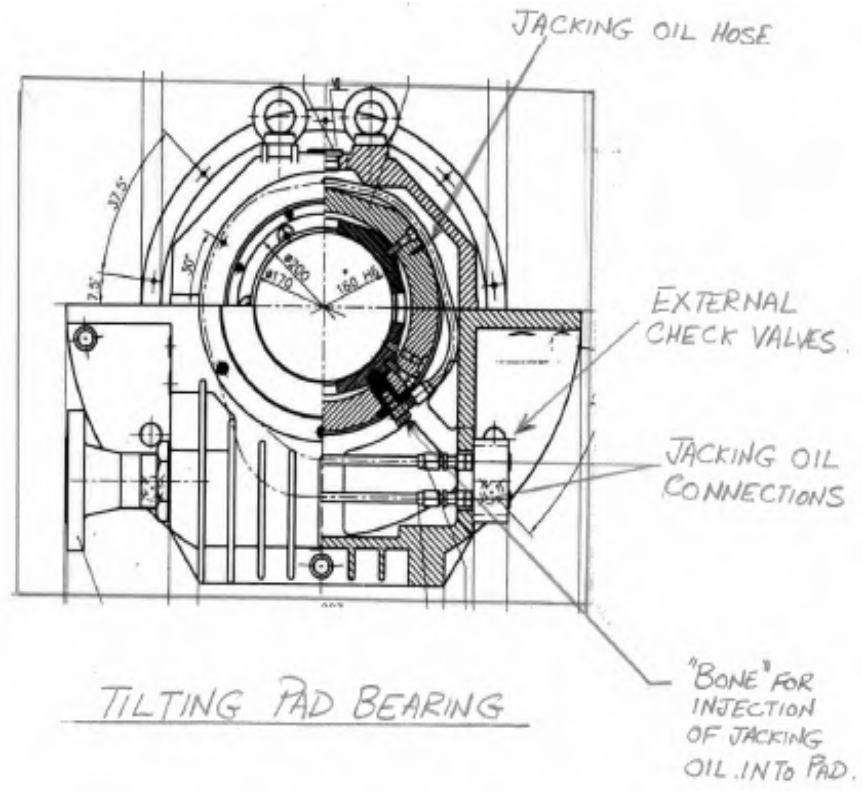


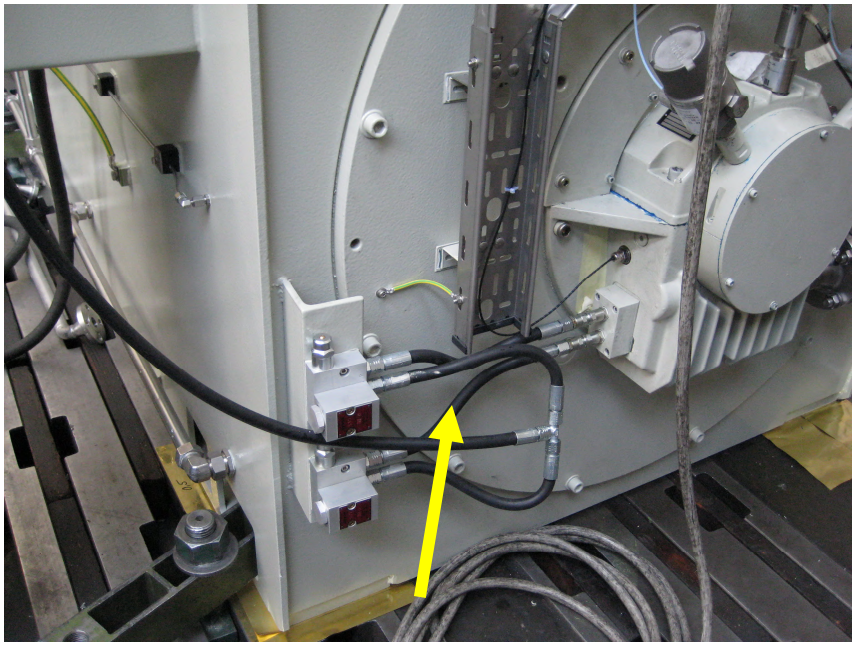
Subsequent Investigations Leading to Resolution

[B] Elimination of Jacking Oil

by disconnection of hoses and plugging of jacking oil ports in pads.

Trapped volume of oil /air between external check valve and port in pad deemed responsible for SSV

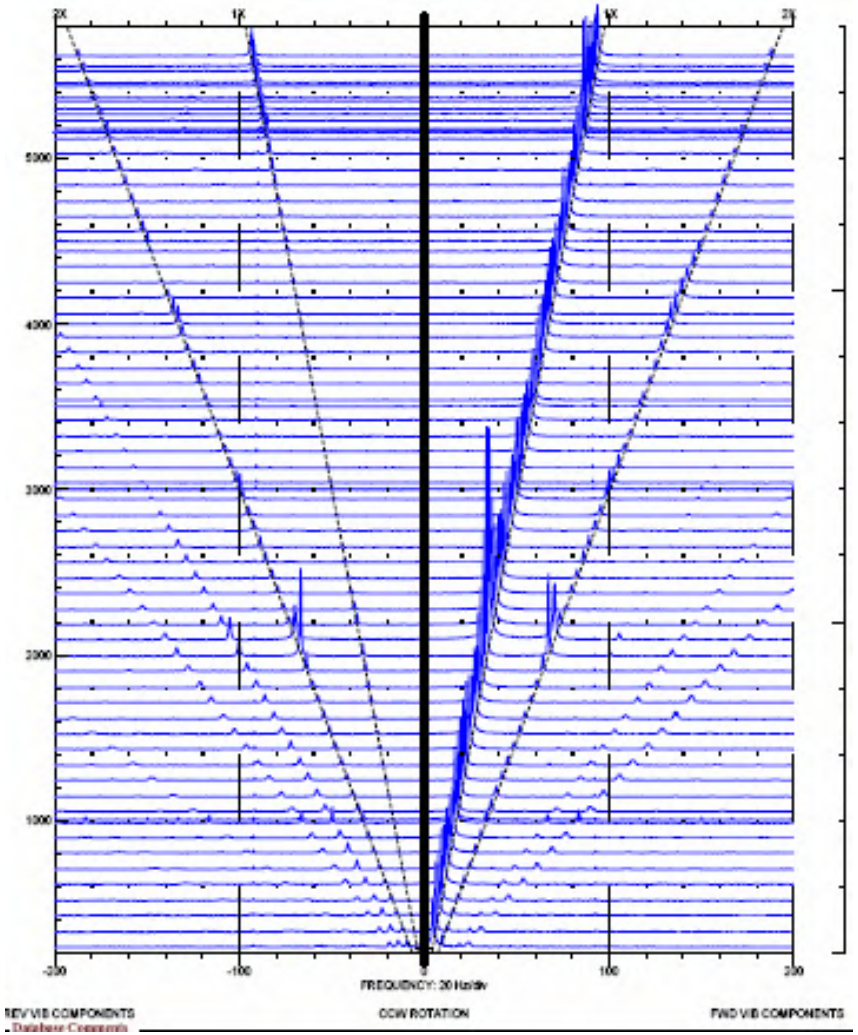




SSV Problem Resolved by Experimental Setup/Fix

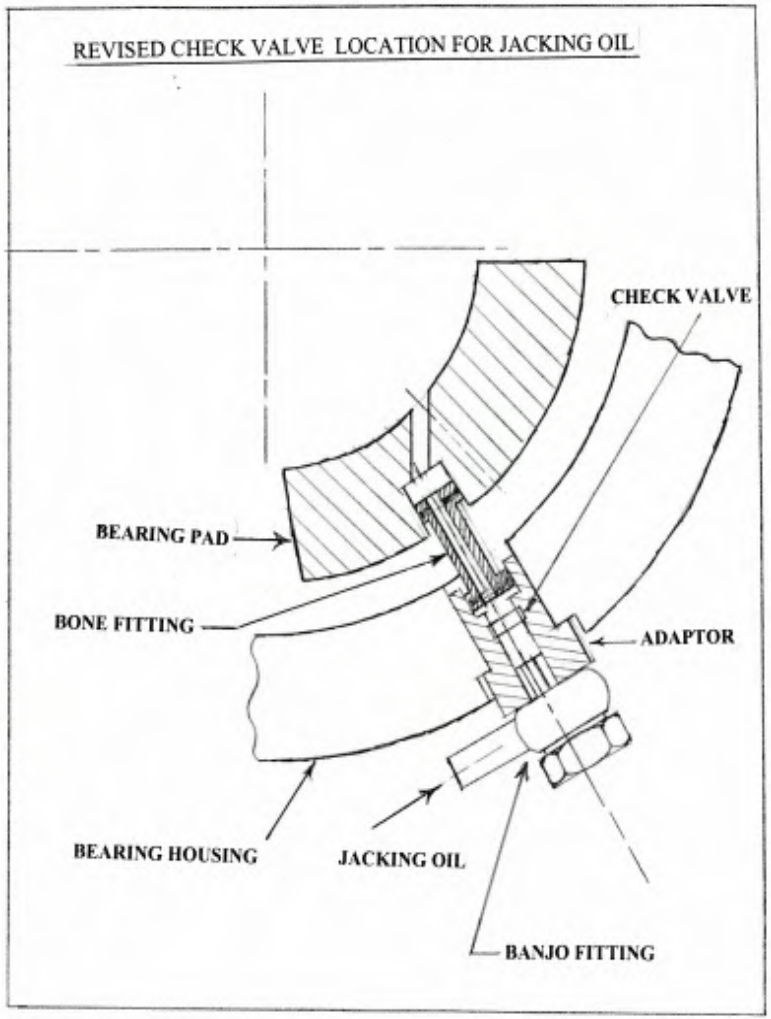
Tests indicated no SSV

Low vibration levels



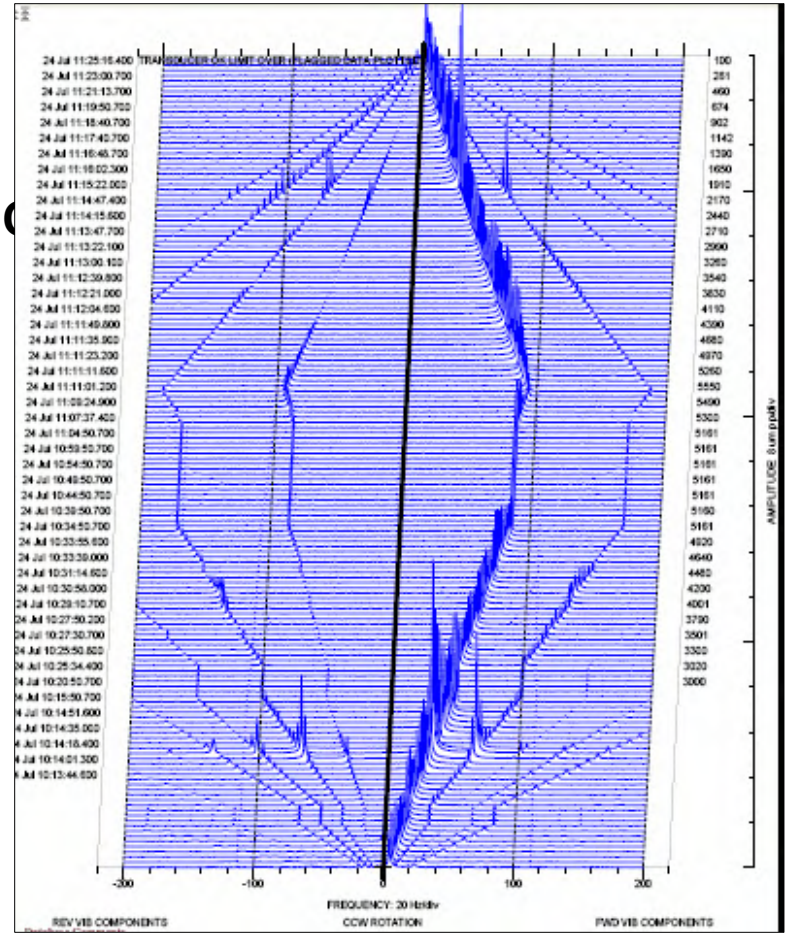
SSV Problem Resolved by Permanent Fix

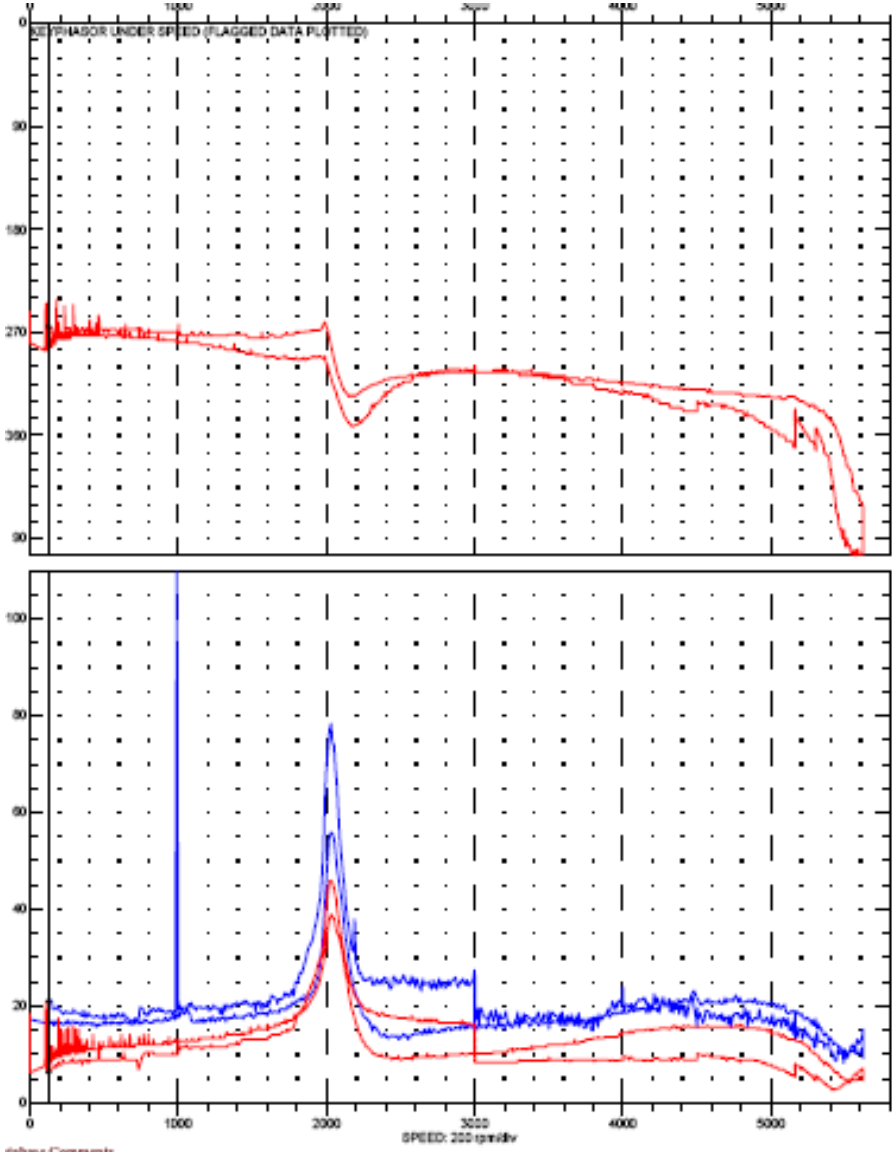
Permanent fix involved installing a check valve in the adaptor near the tilting pad



SSV Problem Resolved by Permanent Fix

Final Test Showed good vibration levels 20 microns at overspeed and no SSV.





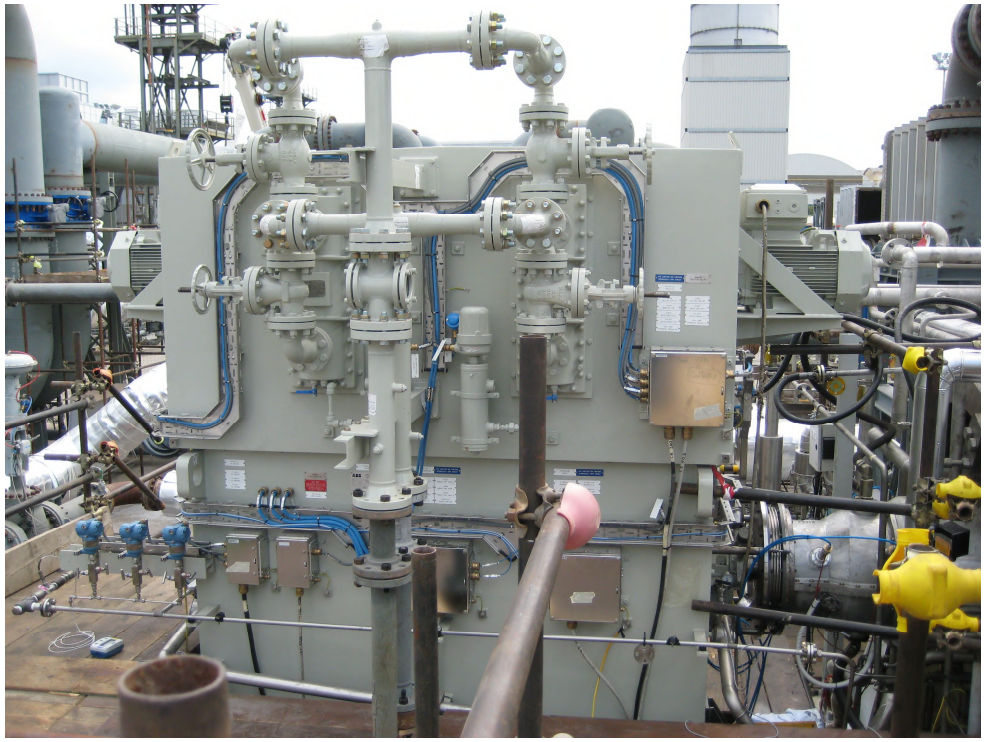
Successful String Test

Problem took 4 months to resolve, FLFS string test conducted successfully

Motor performed very well

Motor Vibration Levels at String test ranged from 15 to 21 microns pk-pk

No SSV noted



Conclusions

High speed motors must be tested at full speed at OEMs facility, NOT for the first time at string test.

Improbable causes must not be discounted

Good / Open communication between OEM, EPC, Machinery Supplier and end user is a must